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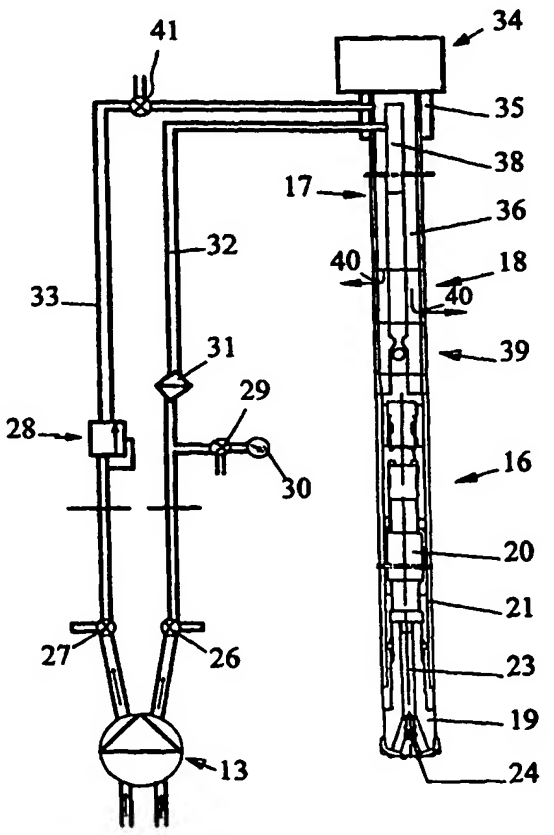
(54) Title: SOIL CONSOLIDATION APPARATUS, TOOL AND METHOD

(57) Abstract

The present invention relates to a soil consolidation apparatus, a tool and a method for soil consolidation. The tool comprises a drill string (17) of one or more drill tubes wherein a second chamber (36) for supplying grout to a jet grouting means (18) in the drill string is provided and a drilling means (16, 19) attached to one end of said drill string. The drilling means is a down-the-hole hammer (16) provided with a drill bit (19) for percussive drilling of a hole in the soil. The jet grouting means (18) is mounted in the vicinity of one end of the down-the-hole hammer (16) and comprising at least one lateral opening (40) in said drill string for jet grouting.



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Soil consolidation apparatus, tool and method

Field of the invention

The present invention relates to a soil consolidation apparatus, a tool and a method for soil consolidation according to the preambles of the appended independent claims.

Background of the invention

The technique of soil consolidation has been used for the static retrofit of existing structures for several years. Soil consolidation is ideally suited for solving foundation problems in areas of tight access, low overhead or difficult geology conditions. A typical method of soil consolidation is to drill a bore by rotating a rotary drill bit by means of a tube string, opening a free end of the string and inserting a ball that through gravity falls on to a seat in the string adjacent to the drill bit. Thus a check valve is created shutting the channel to the rotary drill bit and allowing jet grouting of the soil adjacent to the hole during retraction of the string and the drill bit. When the soil to be consolidated includes big boulders (diameters of 0.3 to 1.0 m) the known method becomes ineffective in terms of penetration speed. When the latter kind of soil is to be consolidated one often also have to use a top hammer equipment wherein the hammer impacts on a sealed drill string which transfers shock waves to a percussive drill bit. When the drill bit has reached its predetermined position down into the soil, jet grouting is commenced at 300 to 500 bars in internal pressure. The shock waves will impair the function of the seals mounted in every drill string joint and the grout will leak and abrade holes in the expensive drill tubes and the jet grouting will be performed at lower pressure than intended. As soon as the leakage is discovered the drill tube is exchanged. Furthermore prior art apparatus necessitates the use of at least two pressurizing means: one compressor to pressurize air and one pump for jet grouting. The air has to be pressurized to a high level for lifting the cuttings and thus the soil surrounding the hole will be eroded.

Objects of the invention

One object of the present invention is to provide a soil consolidation apparatus, a tool and a method for soil consolidation that have the advantages of prior art.

Another object of the present invention is to provide a soil consolidation apparatus which is environment friendly.

Still another object of the present invention is to provide a soil consolidation apparatus which needs only one pressurizing means to function.

Still another object of the present invention is to provide a soil consolidation apparatus which can penetrate the soil at high production rate without impairing the drill tubes.

These and other objects have been attained by a soil consolidation apparatus, a tool and a method for soil consolidation according to the appended claims with reference to the drawings.

Brief description of the drawings

Fig. 1 shows a soil consolidation apparatus according to the present invention. Fig. 2 shows a pump flow chart in connection with a tool according to the present invention. Fig. 3 shows the principal work mode of the soil consolidation apparatus according to the present invention.

Detailed description of the present invention

In Fig. 1 is generally shown the equipment 10 needed for soil consolidation. The equipment comprises a silo 11 for cement, a mixer 12 for mixing water and cement into a grout, a pump 13 having at least two chambers for pumping water and the cement mixture, a control board 14 for controlling the parameters of the equipment 10, and a drill rig 15. The described equipment adheres to prior art and is readily available on the market today.

Now referring to Fig. 2, a down-the-hole hammer 16 is connected to a non-return valve 39, which in turn is connected to a jet grouting monitor 18, which in turn is connected to the drill string 17. The drill string 17 comprises a number of double leads, high pressure drill tubes duly sealed in the thread areas. The

hammer 16 is a hydraulic, preferably water-driven hammer as disclosed in US-A-5,107,944 incorporated by reference. The water driven hammer carries a percussive drill bit 19 as disclosed in US-A-5,645,132 incorporated herein by reference.

The rearward end of the hammer 16 is provided with a drive piston 20 reciprocable in a cylinder. The front end of the piston is guided for reciprocation in a bearing located adjacent an anvil of the drill bit. Between the cylinder and the bearing the hammer is elongated and enlarged diametrically relative to the piston. A port is provided in said rear end for supplying pressurized hydraulic fluid from the drill tube. The enlarged hammer portion reciprocates freely in a chamber formed by an outer casing 21. The casing is mounted to the front end of the drill rod. The drill bit is slidably received and retained by the front end of the casing having a channel extending longitudinally therethrough. Drive water is expelled from the cylinder and flushes the hole drilled by the bit 19. An open ended tubular valve reciprocates to control a duct connecting the interior of the valve to coaxial through-flushing channels 23 in the hammer and the drill bit.

The percussion drill bit 19 includes a drill body having a fluid passage 23 formed therein for conducting flushing fluid to a front drilling face of the drill bit. The fluid passage includes a main portion extending from a rear end of the bit and terminating short of the drilling face, and a plurality of branch lines extending from a front end of the main portion to the drilling face. Front and rear axially spaced seats are disposed in the main portion of the fluid passage. A check valve in the form of a ball 24 is freely movable within the main portion of the fluid passage between contact with the front and rear seats. When the drill bit is subjected to external over-pressure or when it is oriented upwardly and no flushing water is supplied, the ball moves rearwardly into sealing contact with the rear seat so that no water or contamination can flow rearwardly past the rear seat. When flushing fluid is conducted, the flushing fluid pushes the ball forwardly, into non-sealing contact with the front seat and travels past the ball into the branch lines. During downwards drilling, if the density of the ball is less than that of backflowing water, the ball will float upwardly upon the back-flowing water and into sealing contact with the rear seat.

In Fig. 2 is shown the tool in the consolidation apparatus and also shown are the pump 13, manual shut off valves 26, 27, 41, a maximum pressure relief valve 28, a manual relief valve 29, a pressure gage 30, a filter 31, high pressure hoses 32, 33 and a rotation unit 34.

The tool is mounted by having a check valve 39 threaded onto the threaded end of the hammer 16. The jet grouting monitor 18 is threaded onto the check valve 39 and the drill tube is threaded onto the jet grouting monitor 18. An inner pipe or channel 38 is mounted substantially simultaneously as the drill tube.

When the drill rig 15 has been positioned on the location for drilling as in Fig. 1 or 3 having the tool connected to the rotation unit of the drill rig, the valve 26 is opened such that high pressurized water from the pump 13, pressurized up to 80 to 200 bar, will run through the hose 32 and the filter 31, and successively through a swivel 35, the water channel 38 in the drill string 17, an open check valve 39 and into the hammer 16. The piston 20 of the hammer will then impact on the rear end of the drill bit 19, thereby transferring shock waves to the bit buttons impacting on the soil or the rock. If boulders 37 are present in the feed direction of the drill string there will not be a stop in the drilling operation since the tool is constructed for hard rock drilling also. Spent drive water is used to cool the drill bit and to remove drill cuttings in front of the drill bit upwardly outside the drill string and to the surface. The latter is best seen in Fig. 3 I. When additional tool length is required water supply is cut off via the valve 26 and an additional inner pipe 38 and an external tube are mounted, usually every 2 m. When the drill bit has reached its predetermined depth position as in Fig. 3 II the manual shut off valve 26 is closed and the pressure in the hose 32 is relieved by having the pressure running out itself. When water supply is cut off and back-flow of fluid is present the ball 24 will ascend to the rear seat and seal the hammer from any back-flowing fluid. To minimize said back-flow through channel 23 the additional check valve 39 seals the water pipe 38 above the hammer to create a counter pressure if back-flow starts.

The grout may enter into the pump 13 and be pressurized up to maximum 500 bar. Then the valve 27 is opened and the highly pressurized grout will run through the hose 33 and the pressure relief valve 28, and successively through

a swivel 35, a grout channel in the drill string 17 and out through the openings or grout channel ejectors 40 of the jet grouting monitor 18. The grout will not enter into the hammer 16 since the hammer and the water chamber 38 are sealed and separate from the grouting chamber 36. The rotation unit 34 is started to rotate the drill string while retracting it. The lateral jet stream of grout exiting from the openings 40 will mix with the soil present to a diameter of maximum 1 m and will produced a console about as high as the depth of the drilled hole as shown in Fig. 3 II-V. After completion of the consolidation process, the drill string is completely retracted from the drilled hole and often the jet line is flushed with water before the valve 27 is closed. During retraction of the tool the grout supply is cut off via the valve 41 such that inner pipes 38 and an external tube can be dismounted. Then the consolidation apparatus is ready to drill a new hole by opening the valve 26 for a new drill cycle.

It should be noted that the present invention provides numerous additional advantages relative to prior art devices. A water driven hammer will not affect the surrounding soil as much as air driven tools in respect of erosion, oil pollution and noise. For example, in respect of erosion, speed of water to drive the water driven hammer is about 1 m/s as compared to an air driven hammer wherein the air speed is about 20 m/s. The apparatus according to the present invention obviates the need of a compressor. Furthermore by using a water driven hammer the hammer will not be heated and thus the grout will not dry on the hammer to counteract extraction of the hammer.

The invention can be varied freely within the scope of the appended claims. Although the present invention has been described in connection with preferred embodiments thereof, it will be appreciated by those skilled in the art that additions, deletions, modifications, and substitutions not specifically described may be made without departing from the spirit and scope of the invention as defined in the appended claims.

Claims

1. A method of consolidating soil by jet grouting comprising the steps of:
-providing first means (32) for supplying hydraulic fluid ,
-providing second means (11,12,33) for supplying grout,
-providing pump means (13), drilling means (16,19) and jet grouting means (18,40),
-providing a drill string (17) attached to a rotation unit (34) at one end and carrying said drilling means at another end,
-supplying hydraulic fluid and grout to separate chambers (36,38),
-mounting said jet grouting means (18,40) in the vicinity of said drilling means (16,19),
wherein the method comprises the further steps of:
A)-pressurizing said fluid and transferring said pressurized fluid to a down-the-hole hammer (16) for percussive drilling of a hole in the soil,
B)-pressurizing said grout and supplying the grout to a lateral opening (40) in said drill string to form a lateral jet stream of grout,
C)-retracting while rotating said drill string by means of the rotation unit to produce a console of mixed soil and grout having a diameter generally larger than the diameter of the drilled hole.

2. The method according to claim 1, wherein steps A and B include pressurizing said fluid and said grout with a common pump means (13).

3. The method according to claim 1, wherein step A includes pressurizing water and transferring said pressurized water to a water driven down-the-hole hammer (16).

4. The method according to claim 1, wherein step A further includes the step of sealing the hammer (16) substantially at its respective ends before commencing step B.

5. A soil consolidation apparatus comprising first means (32) for supplying hydraulic fluid, second means (11,12,33) for supplying grout, pump means (13), drilling means (16,19) and jet grouting means (18,40), wherein a drill string (17) is attached to a rotation unit (34) at one end and is carrying said drilling means at another end,
characterized in that the drilling means is a down-the-hole hammer (16) provided with a drill bit (19) for percussive drilling of a hole in the soil and in that said jet grouting means (18) is mounted in the vicinity of one end of the down-the-hole hammer (16) and comprising at least one lateral opening (40) in said drill string for jet grouting and in that the first means (32) for supplying hydraulic fluid and the second means (11,12,33) for supplying grout are separate.

6. The apparatus according to claim 5, wherein a common pump means (13) is provided to pressurize separate chambers (36,38) for transfer of grout and water.

7. The apparatus according to claim 6, wherein a water chamber (38) is connected to a water driven down-the-hole hammer (16).

8. The apparatus according to claim 5, wherein the drilling means (16,19) comprises non-return check valves (24,39) for avoiding back-flow of fluid through the hammer.

9. A tool for a soil consolidation apparatus as defined in claim 5 comprising a drill string (17) of one or more drill tubes wherein a second chamber (36) for supplying grout to a jet grouting means (18) in the drill string is provided and a drilling means (16,19) attached to one end of said drill string,
characterized in that the drilling means is a down-the-hole hammer (16) provided with a drill bit (19) for percussive drilling of a hole in the soil and in that said jet grouting means is mounted in the vicinity of one end of the down-

the-hole hammer (16) and comprising at least one lateral opening (40) in said drill string for jet grouting.

10. The tool according to claim 9, wherein a first chamber (38) for transferring pressurized water is provided to drive a water driven down-the-hole hammer (16), said first chamber (38) being substantially surrounded in the drill string (17) by the second chamber (36).

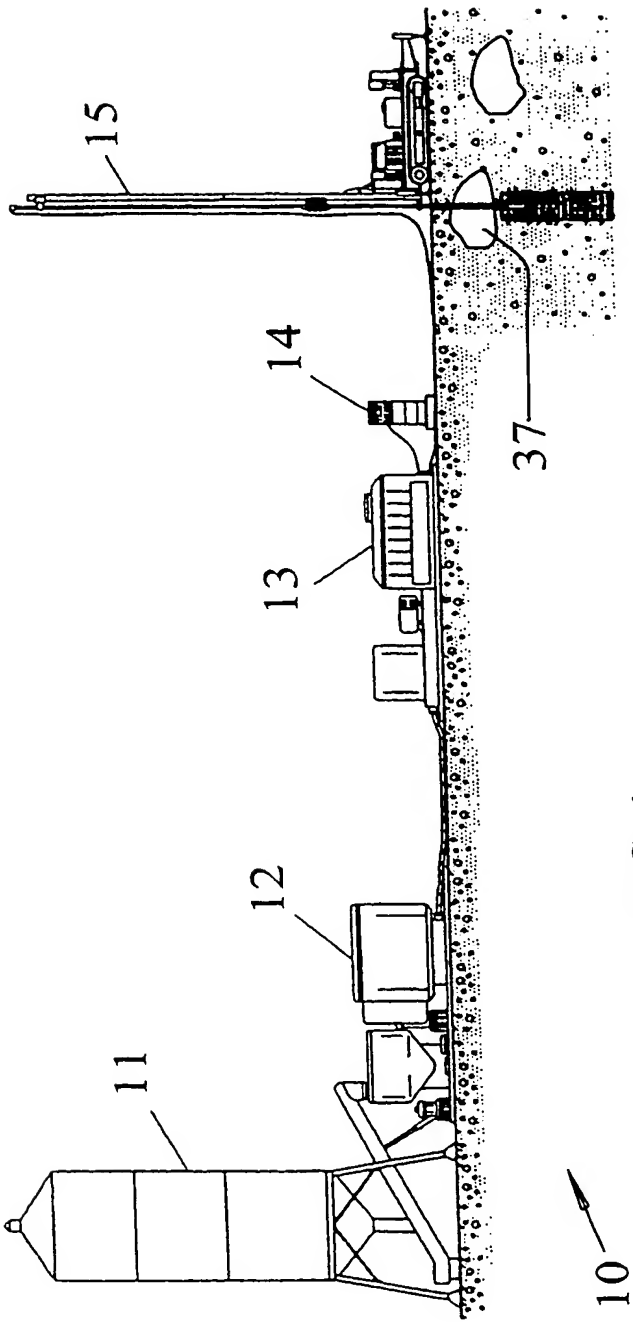

FIG. 1

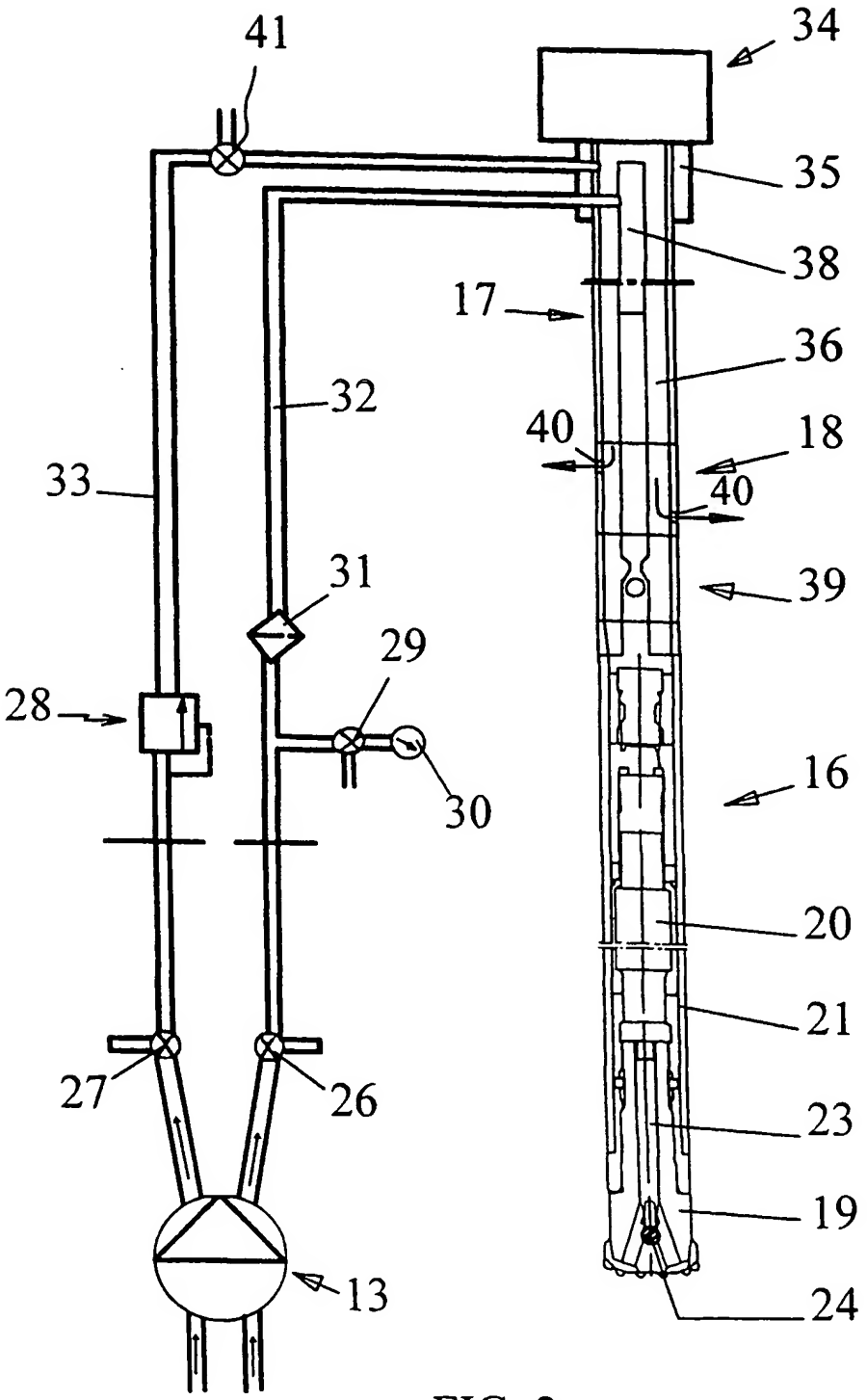
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FIG. 2

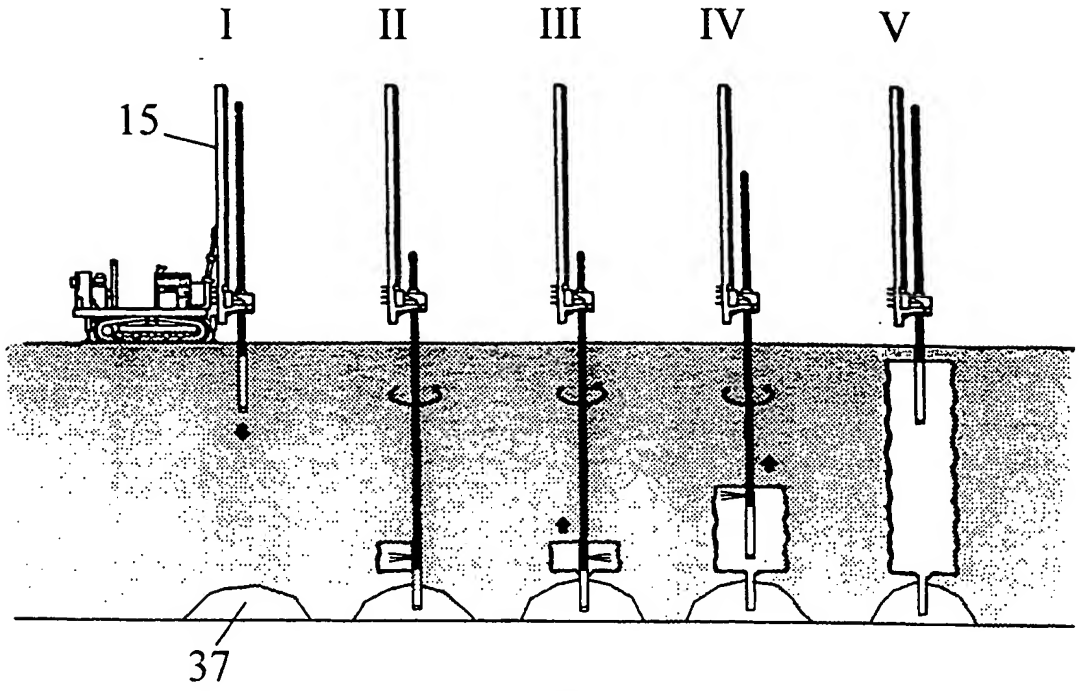

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 98/02013

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: E02D 3/12 // E21B 33/138
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: E02D, E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

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EDOC, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE 19637991 A1 (G. KLEMM BOHRTECHNIK GMBH), 17 April 1997 (17.04.97), column 3, line 37 - line 44, figures 3,4 --	1-10
A	DE 4235378 A1 (BOHRIOCHZEMENTIERUNG GEO-TECHNIK GMBH), 21 April 1994 (21.04.94), column 2, line 43; column 2, line 57, figure 2 --	1-10
A	US 5219247 A (GEMMI ET AL), 15 June 1993 (15.06.93), figure 2, abstract --	1-10
A	US 3800544 A (NAKANISHI), 2 April 1974 (02.04.74), figure 4 --	1-10

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5645132 A (ASBERG), 8 July 1997 (08.07.97), figure 3, abstract -- --------	1-10

INTERNATIONAL SEARCH REPORT

Information on patent family members

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International application No.
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 19637991 A1	17/04/97	DE 29516296 U	07/12/95
DE 4235378 A1	21/04/94	NONE	
US 5219247 A	15/06/93	IT 1246157 B	15/11/94
US 3800544 A	02/04/74	DE 2158764 A,C	22/06/72
		FR 2116171 A	07/07/72
US 5645132 A	08/07/97	CA 2198556 A	04/09/97
		SE 9700679 A	05/09/97